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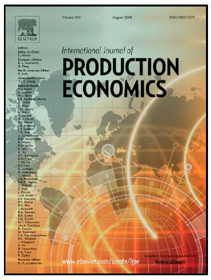

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Impact of Lean and Innovation on Sustainability Performance of Small and Medium Sized Enterprises: A Data Envelopment Analysis-based Framework

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Abstract:

Lean and Sustainability Oriented Innovation both enhance competitiveness of small and medium enterprises (SMEs) in a sustainable way. Lean is efficiency focused, whereas sustainability oriented innovation emphasizes on responsiveness. Although lean and sustainability oriented innovation have been separately researched, there is a gap in knowledge on the combined effect of lean and sustainability oriented innovation (SOI) on SMEs supply chain sustainability. SMEs have limited resources and face numerous competition. Therefore, their supply chain sustainability can only be achieved through most appropriate trade-off between economic, environment and social aspects of business. The purpose of this paper is to understand the combined effect of sustainability oriented innovation and lean practices, on supply chain sustainability performance of SMEs. The study uses a Data Envelopment Analysis (DEA) based framework and applies this to a group of SMEs within the Eastern part of India. Lean and sustainability oriented innovation are considered as input criteria, and economic, operational, environmental and social aspects are considered as output criteria of the proposed framework. DEA segregates inefficient SMEs and suggests at least a SME to benchmark. Subsequently, the study undertakes qualitative approach to suggest improvement measures for the inefficient SMEs. The results reveal that combined lean and SOI helps achieve SMEs' supply chain sustainability. The findings are useful for policy makers and Individual SMEs' owners and managers to undertake measures for improving sustainability. Theoretically this research contributes a DEA-based framework to study the effect of combined lean and SOI on sustainability that helps improving SMEs' sustainability performance.

Keywords Small and Medium Enterprises, Supply chain sustainability, Sustainability-Oriented Innovation , Data Envelopment Analysis

Paper type Research Paper

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1. Introduction:

Small and medium sized enterprises (SMEs) make up around 90% of the world's businesses (Head, ISO) and employ 50-60% of the world's population (Organisation for Economic Co-operation and Development Staff, 2000). SMEs in the Indian manufacturing sector, contribute significantly to Indian gross domestic product (GDP). While it is widely accepted that SMEs play a significant role in the economic development of any country, they also exert considerable pressure on the environment, not individually, but collectively (Speier, Mollenkopf, & Stank, 2008). It has been estimated that SMEs contribute up to 70 percent of global pollution collectively (Hillary, 2000). Available research data suggests that SMEs are responsible for more than 50% of the industrial pollution in the Asia-Pacific region and there are numerous examples which suggest that SMEs contribute significantly to environmental damage and GHG emissions (Whitehead, 2013). Additionally, recent survey reveals that SMEs consume more than 13% of total global energy demand (around 74 exajoules (EJ)). Cost-effective energy efficiency measures could shave off as much as 30% of their consumption, namely 22 EJ, which is more energy than Japan and Korea combined consume per year (IEA 2015).

Indian manufacturing SMEs contribute to 45% of India's manufacturing output and 17% of India's GDP. It gives employment to approx. 40% of India's workforce (Dubal, 2016). A major concern of any business firm (small or large) is to remain sustainable throughout the products/services life cycle. Sustainability in SMEs could be achieved through most appropriate trade-off among economic, environment and social pillars (Tajbakhsh & Hassini, 2015, Piercy and Rich, 2015; Ogunbiyi et al., 2014; Miller et al., 2010). SMEs businesses are challenging from both demand and supply sides. On the demand side, on one hand, the original equipment manufacturers are very demanding and on the other hand, the number of competitors is numerous. In the supply side, adhering to various regulations and managing procurement are also very challenging. Therefore, SMEs tend to be more economic focused without showing much concern to environmental and social aspects for survival unless environmental and social measures provide higher cost savings. Studies have also revealed that SMEs' environmental and social practices are driven by the customers' needs and governmental regulations.

Sustainability has become an imperative responsibility for enterprises to survive in the current society due to the threats created by traditional manufacturing practices, and regulations imposed by stakeholders and policymakers. There has been growing pressure on the SMEs stemming from adverse global economic and climatic conditions, to integrate various supply chain paradigms (such as lean, innovation) for meeting the demands of the customer efficiently and effectively, while adhering to the environmental and social requirements. This has motivated both SMEs and researchers to identify different approaches for implementing sustainable operations that will lead to competitiveness. SMEs need a framework allowing them to identify and implement their sustainability development scheme requested, not only by the stakeholders, but also by individual SMEs of the supply chain systems (Hsu, Chang, & Luo, 2017). In view of the above, to achieve sustainability SMEs need to consider economic, environmental and social aspects across their entire supply chain.

Lean refers to continuous improvement and improves quality and productivity by taking cost and waste out of all operations (Machado & Leitner, 2010). Innovation refers to the commercialization of newly designed and implemented products or processes (Van de Ven, 1986). Lean and innovation are two driving forces of today's business success. Lean approach is efficiency focused and innovation has responsiveness priority that emphasizes on customers' satisfaction. Sustainability Oriented Innovation(SOI) is defined as the steps taken in process of

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integration of the social, economic and environmental approach of the product, process and organisation (Klewitz et al., 2014).Although the impact of lean approach and SOI (Williamson et al., 2004; Tan et al., 2015; Lii and Kuo, 2016; Jabbour et al., 2015) on sustainability have been separately researched, there is huge knowledge gap on combinative effect of lean and sustainability oriented innovation on SMEs supply chain sustainability. Supply chain sustainability can be achieved through most suitable trade-off between economic, environmental and social aspects of business. However, with fundamentally different concepts, some aspects of lean may negatively affect a company's capability to be successful with certain types of innovations (Chen & Taylor, 2009). Similarly, certainly type of innovation may not be cost effective but could contribute to better environmental and social performance. Therefore, the combined impact of lean and sustainability-oriented innovation on sustainability performance of SMEs' supply chain is important to achieve competitiveness. The overarching aim of this paper is to facilitate SMEs to achieve sustainability but specifically intends to reveal the combined effect of lean and SOI on sustainability performance.

The rest of the paper is organised as follows. In Section 2, we critically analyse contemporary research on impact of lean and sustainability-oriented innovation on sustainability and identify research gaps. In Section 3, we state the methodology of this research. Section 4, we define the DEA measurement model and in section 5 we demonstrate the DEA application framework supplemented with the results. Section 6 covers the research discussion, followed by the conclusion in section 7.

2 Literature review

The literature review has been classified into following sections:

2.1 SMEs Supply Chain Sustainability

According to Seuring (2008) sustainable supply chain management is defined as the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements. The SMEs are a critical part of the supply chain of the bigger companies (Seuring & Müller, 2008). A bigger organisation transfers the pressure of sustainability on to its suppliers who are majorly SMEs, thus sharing both risk and responsibility (Dey & Cheffi, 2013). Sustainability triple bottom line framework has major focus on the economy, environment and social aspects of the organisation (Elkington, 1997). The operational and economic aspects of the SMEs are the essential targets to produce goods and to gain revenue. However environmental and social performance, as well as their economic efficiency tend to conflict in their nature of contribution of sustainability (Tajbakhsh & Hassini, 2015).

It is believed that the environmental damage caused by SMEs will grow unless innovative strategies are devised. There are, however, a number of barriers that prevent SMEs from achieving such innovative strategies and these include: a lack of information on the cost-benefits of improving environmental performance, weak external pressure / incentives, lack of internal capacity (e.g. financial resources, human resources, technologies, business processes and R&D activities), weak supporting frameworks and in many cases political indulgence by policy makers (Zhu & Sarkis, 2004; Dey & Cheffi, 2013). Hence SMEs struggle in achieving Supply chain sustainability.

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2.2 Lean practices

The concept of lean has evolved from the Japanese manufacturer, Toyota Motor Corporation, focusing primarily on the reduction of waste in operations (Herron and Hicks, 2008; Ōno, 1988). In the existing operations management literature, the definition of lean practices provides different perspectives to accomplish lean. For example, lean enables the businesses to engage with an efficient value creation process. Additionally, lean is linked to productivity, and customer satisfaction, which will eventually lead to improvement in quality, speed of the process and reduction in cost. In summary, the existing studies looking at integrating lean and sustainability have often limited the lean philosophy to reducing waste at operational level (e.g. Lapinski et al., 2006; Green et al., 2010; Cabral et al., 2012; Miller and Sarder, 2012) or quality management (Zhu and Sarkis, 2004). In this context, consolidating the lean literature, Piercy and Rich (2014) have identified two levels of lean operations, i.e. adopting them in the workplace primarily focusing on the operational improvements, and in devising business strategy to address environmental and community concerns.

2.3 Lean practices and sustainability

Piercy and Brammer (2012) identified lean principle help to improve the overall sustainability with the six dimensions: Workplace - Improve working conditions through higher level of safety, training and incentives (Taubitz, 2010), Environment - Optimal usage of resources to reduce waste and environmental impact (Piercy and Brammer, 2012), Quality - Lean operations aim to improve the quality of product and services provided to clients (Womack and Jones, 2005), Supply chain - Developing long-term relationship with suppliers to reduce costs, wastage and improve quality is fundamental to lean management (Lamming, 1993), (Simpson and Power, 2005), Governance and Ethics - Transparency of information corresponding to the management practices is a core driver of lean management (Lamming, 1993), Community - Maintaining a positive reputation is a core principle of lean management (Womack and Jones, 2005).

2.4 Sustainability Oriented Innovation (SOI)

Sustainability oriented innovation refers to the direction which requires management of the economic, social and ecological aspects (Klewitz et al.,2014) so that they can become integrated into design of new products, process and organization structure (Rennings,2000). SOI primarily consists of product innovation, process innovation and organization innovation primarily focusing on the improvement of the sustainability of the organization (Klewitz et al.,2014; Altenburg et al.,2012). SMEs innovate differently than traditional innovation. Process Innovation refers to the solutions adopted to improve the process goods and services (Adams, 2016). It aims to improving the eco-efficiency of the company. The major focus is on cleaner production. Organisation Innovation refers to the reorganization of the routines and structures within firms to focus people and organization. It includes formalized management system such as the environmental systems. Implementing Environmental Management System (EMS) including ISO 14000 is a typical example of organisational innovation for environmental sustainability (Wu 2017).

2.4 Lean practices and Sustainability Oriented Innovation (SOI) on SMEs Supply chain sustainability

Lean process focus primarily to reduce costs and sustainability oriented innovations focuses to create new business value by transforming original ideas to process or services that satisfy customers' certain needs, and thus enlarge the market size and strengthen a company's overall competitiveness (Chen & Taylor, 2009). However, the existing literature integrating lean to sustainability have primarily focused on the philosophy of reducing waste to deliver environmental benefits. The lean, supply chain and sustainability has been critically reviewed (Martínez-Jurado & Moyano-Fuentes, 2014). Lean Management Practice has been extended to SMEs' supply chain through eliminating waste, enhancing quality, reducing costs and increasing flexibility across supply chain in different tiers (Inman and Green 2018).

However, with fundamentally different concepts, some aspects of lean may negatively affect a company's capability to be successful with certain types of innovations (Chen & Taylor, 2009). Piercy et al. (2015) suggest innovation orientation is required for adopting lean. Lean practices result in an overall decrease in organizations' innovativeness (Lewis, 2000). Lean approach is efficiency focused, and sustainability is the most appropriate trade-off among economic, environmental and social practices (Piercy & Rich, 2015). Studies have highlighted lean adoption leads to sustainability (Moreira et al. ,2010). Achieving sustainable business performance requires sustainability-oriented innovation, which is different from traditional innovation.

The existing research have tried to develop the relationship between lean practices (Inman and Green,2018) and sustainability-oriented innovation (Klewitz et al.,2014; Adams, 2016) separately with sustainability. For improving sustainability, the lean practices are required (Inman and Green,2018). Lean approach is efficiency focused and innovation has responsiveness priority that emphasizes on customers' satisfaction. There is a research gap on the study of combined impact of lean and sustainability-oriented innovation on supply chain sustainability of SMEs. The research aims to bridge the gap by studying the combined impact of sustainability-oriented innovation and lean practices on the SMEs supply chain sustainability.

2.3 Supply chain sustainability and relevant methods:

Supply chain sustainability can be achieved through a trade-off between the efficiency and responsiveness dimensions across the supply chain drivers (e.g., facilities, transportation, inventory, information, sourcing and pricing), through consideration of environmental and social criteria, along with customers' requirements, when making decisions in strategic, planning and operational levels. Although lean approach and sustainability oriented innovation (Williamson et al., 2004; Tan et al., 2015; Lii and Kuo, 2016; Jabbour et al., 2015) have been separately researched, there is a gap on combined effect of sustainability oriented innovation and lean on SMEs supply chain sustainability. Understanding the combined impact of lean and sustainability oriented innovation to achieve sustainability helps SMEs to decide means for improving sustainability performance through adopting most appropriate combined SOI and lean approach. Therefore, there is a need to study the impact of lean and SOI on SMEs supply chain sustainability.

The supply chain characteristics of SMEs vary from that of the large organisations. Large organisation supply chain performance measures are decided by perfect delivery, order fill rate, inventory turnover etc. while that of SMEs are more focused on the internal failures, inventory costs, customer services, productivity etc. (Thakkar,2007). SMEs supply chain face frequent changes in their order and has comparative shorter lead time. SMEs have more flexibility in their process which poses as their advantage over the large organisation. As SMEs have distinct supply chain characteristics, the conventional large organisation supply chain performance measurement model cannot be used for SMEs sustainable supply chain measurement. The existing literature have used lifecycle assessment, equilibrium models, statistical sampling, case study and action research for large companies' sustainable supply chain measurement (Taticchi et al.,2015). In the existing methods however, the distinct SMEs' characteristics and Critical Success Factor could not be measured and improved. Thus, from above argument, there is a need for an innovative SMEs supply chain sustainability framework which will help SMEs in measuring and improving the sustainability of SMEs' supply chain.

There are many analytical models and the indices present to measure performance of sustainable supply chain of organisations (Tajbakhsh & Hassini, 2015). Generally critical Indicators are derived to measure the supply chain performance of the organisation. The traditional method of measuring the supply chain efficiency is "spider", "radar" or "z" chart (Wong, 2007). The technique is graphical based so it leads to inconvenience in multiple input and output. Another method is of ratio but it is difficult to capture all the set of ratios into one judgement (Shen, 2013). Supply chain characteristics requires a multiple factors performance measurement model. Multi criteria decision making (MCDM) approaches (e.g. the Analytic Hierarchy Process, the Analytic Network Process, Fuzzy theory etc.) have been used for evaluating the performance of the supply chain (Bhattacharya et al., 2014) but the method neither be used for assessing the large number of organisations nor for an individual organisation. Balanced Score Card and the supply chain operations reference (SCOR) model have been used to measure the efficiency of the supply chain (Brewer, 2000). However, availability of accurate quantitative data on SMEs' performance is challenging (Shepherd & Günter, 2010). Table shows the comparative analysis of the methods used in Supply Chain Sustainability. The existing analytical methods also require to quantify individual constructs and the Critical Success Factor for the performance measurement of sustainable supply chain. Hence there is a knowledge gap in how to measure the sustainable SMEs supply chain and suggest improvement solutions. Moreover, this research intends to reveal the impact of lean and sustainability-oriented innovation on sustainability so as to suggest enhancing sustainability performance through combined lean and sustainability oriented innovation. According to the authors' knowledge, there is no work that has measured relationship of lean and sustainability-oriented innovation with sustainability performance objectively. Table 1 shows the comparative analysis between the methods used for Supply Chain Sustainability

Table 1 Comparative analysis of the methods used for Supply Chain Sustainability

S.No	**Methods to measure the supply chain sustainability of SMEs**			
	Method	**Application**	**Negative**	**Citation**
1	Multi criteria decision making	GSCM, Sustainable supply chain	It cannot be used for analysis of more than a certain number of case studies	Gunasekaran and Kobu (2007), Schaltegger and Burritt, (2014). Dey and Cheffi (2013) Singh et al., (2007), Bhattacharya et al., (2014)

2	Supply Chain Operation Reference(SCOR)	Uses performance metrics to evaluate	Cannot be used for large sample	Taticchi et al.,(2012); Bai and Sarkis (2014)
3	Balanced Score Card(BSC)	Organisation performance from financial perspective	Lack to integrate all sustainability dimension and supply chain members	Reefke and Trocchi(2013),Kaplan and Norton (1992), Tseng et al.(2015)
4	Life cycle assessment	Environmental supply chain design, carbon footprint performance evaluation, evaluating environment performance	Does not include all aspects, the social standards missing	Seuring(2013); Croesand Vermeulen (2015); Matos and Hall (2007); Simao et al. (2016); Park et al. (2016)
5	Fuzzy set approaches	Sustainability performance of Supply chain	Cannot be used for large sample	Erol et al. (2011)
6	DEA	Multi-level DEA used for analysis the efficiency between and among the units	Can be used for Improvement of sustainability	Tajbakhsh and Hassini (2015); Mirhedayatian et al. (2014)
7	International standards and composite indicators	ISO 14001 used as the proof of environmental performance of the supplier selection	Not much relevant to SMES as SMEs have unique characteristics than that of large organisations	Vermeulen and Metselaar (2015)
8	Conceptual framework	Initial model which can be used for sustainability assessment of a company	Case specific	Azevedo et al., (2012); Goyalet et al., (2018); Lee and Wu, (2014); Santiteerakul et al.,(2015); Shokraviand Kurnia, (2014);Sloan (2010) Varsei et al., (2014)

Data envelopment analysis(DEA):

Data Envelopment Analysis (DEA) developed systematically by Charnes (1978), is a non-parametric technique to evaluate the relative efficiencies of a set of comparable decision making units (DMUs) by mathematical programming. DEA is a linear programming technique that provides dynamic collective comparative results for evaluating the productivity of organizations based on multiple inputs and outputs (Muhammet, 2014). The idea is to make a comprehensive supply chain performance measurement system that can capture the total supply chain performance. Using the capabilities of DEA to assess sustainable supply chains performance (Cooper, Seiford, & Zhu, 2011). In DEA the input output model is to be designed such that the ratio of weights does not ask for the exact weight of each criteria. Taticchi et al., (2015) developed the performance measurement for the sustainable supply chain for the big companies. DEA has been used to measure the sustainability of the supply chain networks for big companies (Tajbakhsh & Hassini, 2015).

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DEA has been used in recent literature to study the sustainability (regional, national and supply chain issues). In initial studies DEA is used to focus on environment sustainability considering only economic and environment dimensions (Zhou et al., 2018). Existing DEA models have used the secondary data to analyse the sustainability by traditional DEA BCC (DEA model by Introduced by Banker, Chames and Cooper (1984)), model. This study aims to reveal impact of lean and sustainability oriented innovation practices on sustainability performance of SMEs' supply chain and calls for developing a framework for SMEs' sustainable supply chain performance measurement considering lean and sustainability oriented innovation practices as input criteria and sustainability performance i.e. economic, environmental and social as output criteria. Due to the nature of the criteria this study uses the perceptions of the stakeholders of the case study companies in order to quantify the inputs and outputs of the DEA model. DEA model helps segregate efficient and inefficient SMEs on the basis of right combination of lean and sustainability oriented innovation practices vis a vis sustainability performance. The inefficient companies are allowed to benchmark their performance with their peers to derive improvement measures with respect to lean and sustainability oriented innovation practices that need to be fixed. According to authors' knowledge, there is no research that uses DEA to measure efficiency with respect to adopting right combination of lean and sustainability oriented innovation practices to achieve sustainability performance

3. Methodology: This study employs both qualitative and quantitative approach to conduct interview-based case studies, as shown in Figure 1. This research tries to study the impact of lean practices and SOI on the SMEs sustainability. There is currently little discussed about the impact of SOI and Lean practices together on the SMEs sustainability. Hence this study tries to opt for an exploratory approach by interview case studies. The use of interview method and case study for exploratory type of research is well established in research (Voss et al.,2002; Yin, 2008).

A review of existing literature was conducted to serve two purposes: (1) identify the constructs for sustainability, lean and sustainability-oriented innovation that will aid in identifying characteristics of SMEs. This will aid in formulating a questionnaire with an array of questions representing each construct that will be used in the case-study; (2) developing the DEA model, with input and output variables drawn from the constructs identified in (1). The questionnaire comprised of both objective type questions (linguistic variable used for rating) and subjective type questions (to get qualitative feedback), which will aid in understanding the characteristics of SMEs. 35 manufacturing SMEs from eastern part of India, which are registered with Federation of Small & Medium Industries (FOSMI) were recruited to conduct the case study. The case study took the form of semi-structured interviews with 4 respondents in each SME. SMEs have lesser organisational hierarchy compared to larger organisation, hence 4 respondents from each case SME was considered as adequate. The study was conducted in between 2016 to 2017. Table 2 represents the sample demographic of the case study conducted on sample SMEs.

Table 2. Sample demographics summary

Title	Percentage	Title	Percentage
Owner	2	**Firm age (years)**	
Production manager	20	Less than equal 5	11
Marketing manager	11	5 – 10	44
Supply chain manager	40	10 – 20	24
Purchasing manager	15	Greater than 20	21
Quality manager	*2*	**Number of employees**	
Maintenance manager	*10*	10 - 50	30

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Industry category		50 - 150	40
Primary metal manufacturing	17	150 – 250	30
Fabricated metal product	15	**Respondent location**	
Manufacturing	41	India-West Bengal	100
Electrical equipment and components manufacturing	17	**Years in current position**	
		Less than 5	9
Chemical manufacturing	*10*	6 - 10	60
		More than 10	31

For each case SME, each response to the objective type questions was first translated from the linguistic variable to a numerical variable. Next, the responses from all the four respondents were consolidated, and the mean value was calculated, for each objective type question. Finally, the data was processed into the excel sheet shown in the Appendix A. A data sheet was used to run the sustainable supply chain performance DEA model. The results from DEA (Table 2) are used to identify efficient and inefficient SMEs (using VRS – Variable Return to Scale values). Next, for benchmarking, peers are assigned to inefficient SMEs. The peer assignment is followed by analysis of the practices for both inefficient and peer SMEs, which will be used to making recommendations for improving the sustainability performance of inefficient SMEs through a proper trade-off between lean practices and sustainability oriented innovation. Figure 1 shows the research framework adopted for conducting the study.

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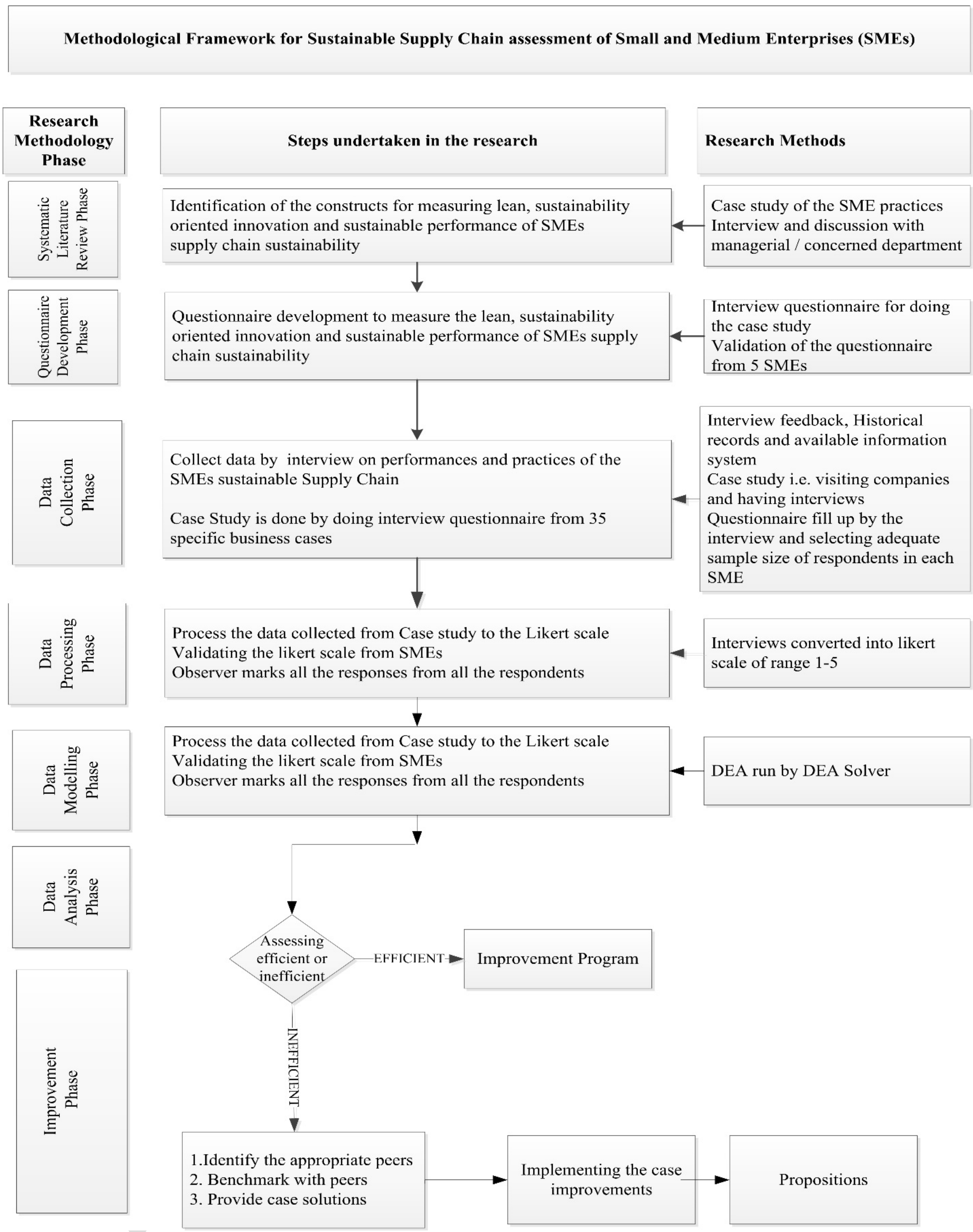

Figure 1 Research Methodology

4 Input oriented BCC DEA Model Formulation

In this study, the 'BCC input-oriented model' of DEA proposed by Banker et al. (1984), under the assumption of VRS has been formulated because this model is output translation invariant.

We have 35 DMUs (each DMU representing an SME), where every DMU_j, j = 1, 2,…,35, produces the same 4 outputs (i.e. performance variables) in different capacity, y_{rj} (r = 1,2, …,4), using the same 2 inputs (lean practices and sustainability oriented innovation), xij (i = 1,2), in different amounts. The efficiency of a specific DMU can be evaluated by the above BCC, in 'envelopment form', as follows:

Min θ_k^{BCC} where x are inputs, y are outputs (1)

$\sum_{i=1}^{2}\sum_{j=1}^{35}\lambda_j x_{ij} \leq \theta_k^{BCC} x_{ik}$ (2)

$\sum_{i=1}^{4}\sum_{j=1}^{35}\lambda_j y_{ij} \geq y_{ik}$ (3)

$\sum_{j=1}^{35}\lambda_j = 1$ (4)

$\lambda_j \geq 0$ all are positive (5)

where θ_k is the radial efficiency factor showing the rate of reduction to the input levels of firm k; λj is the intensity factor showing the contribution of firm j in the derivation of the efficiency of firm k; s_i^- ; s_r^+ are slack variables accounting for extra savings in input i and extra gains in output r. The above problem is repeated 35 times to cover all SMEs. Every time the corresponding linear programming problem is solved to give each SME's efficiency ratingθ. Firms with solution θ =1 are considered as relative efficient or benchmark firms and determine the efficient frontier, while firms for which θ < 1 are considered to be inefficient.

Selection of variables: The DEA model will use a set of input and output variables to determine the efficiency of each DMU (relative to other DMUs). The sustainability performance is considered as output variable in the input-based DEA model. This is based upon the Critical Success Factor of SMEs, which has been identified during case study and drawn from the sustainability literature presented in Table 1. However, the SMEs have revealed that it is economically challenging to implement lean practices. It encouraged us to separate economic constructs and operational constructs in sustainability performance measurement.

SMEs suffer from resource constraint, lack of resources, lack of formalised planning, and difficulty in attracting finance, which prevents them from effective engagement in the sustainability oriented innovation process. SMEs innovate differently compared to a larger organisation because the former have different organisational structure, strategy and policies in place. Sustainability oriented innovation intended for SMEs aims to redesign operations within the value chain to produce goods and services. Sustainability oriented innovation has been categorised as process innovation, organisation innovation and product innovation (Klewitz et. al, 2016). In this context, the process innovation consists of: cleaner production, waste handling and logistics. The product innovation consists of: eco design, life cycle analysis, alternative materials, design, waste handling, and eco-efficiency. The organisational innovation consists of: EMS, ISO 14001, Environmental Management System, Innovation process, Supply chain management, and organisation structure including stakeholders' vision. The driving factors to implement lean in SMEs are reduction in cost, reduction in inventory, lead time, improved quality and reliability of products delivered to supplier and customer (Zhou, 2016). Hence, the questions asked for implementation of lean practices in SMEs during

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the case study take into account inventory, number of employees, lean practices performed, effectiveness of lean practices, demand forecast, effectiveness of inventory management, inventory management policy, capacity utilization, and customer feedback. The motivation is to understand the effect of lean practices and sustainability-oriented innovation on sustainability (output variable), so the lean and sustainability-oriented innovation constructs are taken as input in the DEA model. The existing literature helps in identifying the constructs of lean and sustainability-oriented innovation. Table 2 shows the constructs for the lean and SOI. Figure 2 shows the constructs identified from the Table 3. Figure 2 highlights the constructs and their commonalities derived from literature.

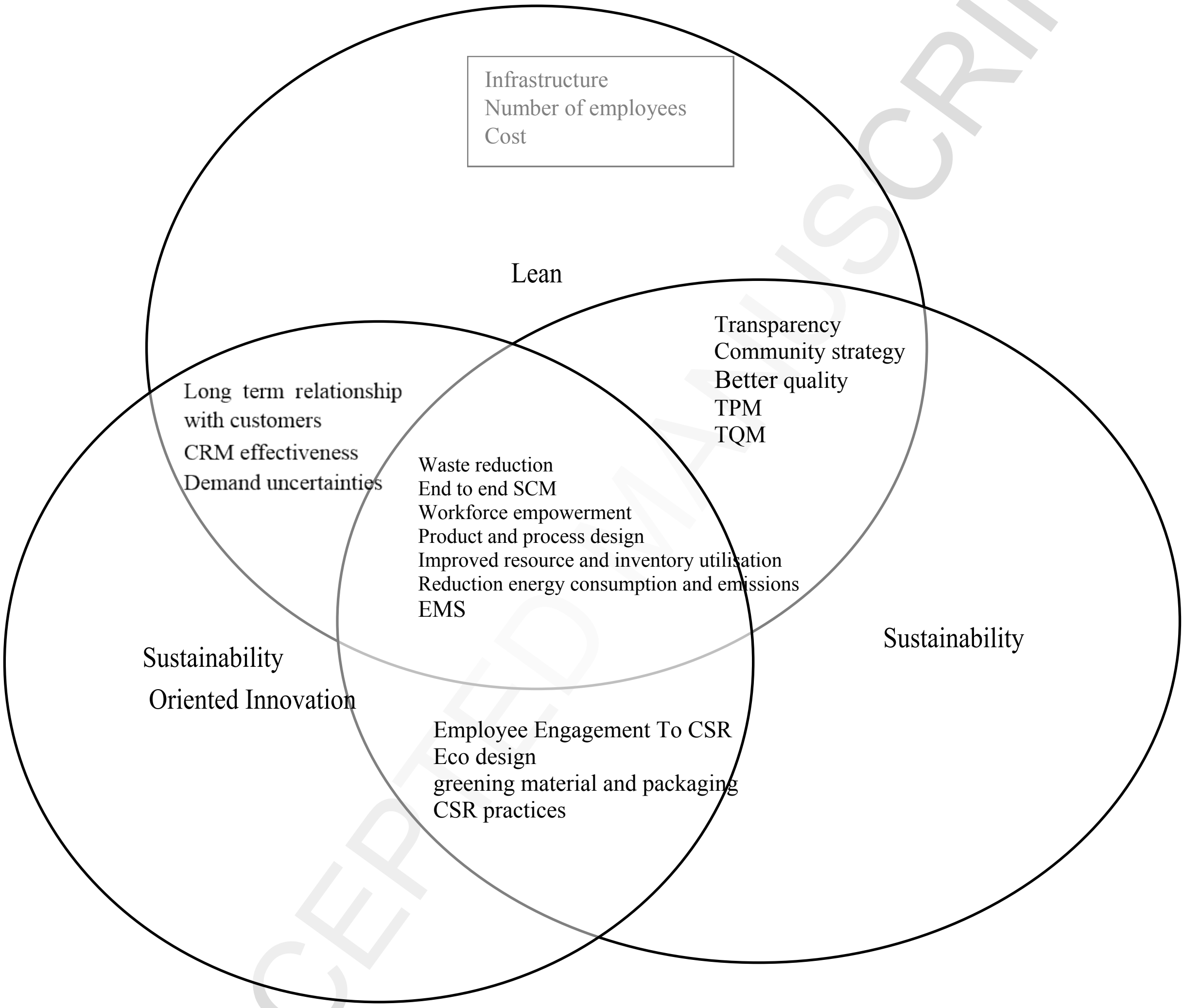

Figure 2 Lean, Sustainability-Oriented Innovation and Sustainability

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Table 3. Constructs for sustainability performance

	Constructs	Citations
Lean Practices	Cost	Abdul-Rashid et al., 2017 Inman and Green,2018 Piercy et al., 2015 Piercy and Brammer ,2012
	Infrastructure	
	Number Of Employee	
	Transparency	
	Community Strategy	
	Better quality	
	TPM	
	TQM	
	Long Term Relationship With Customers	
	CRM Effectiveness	
	Demand Uncertainty	
	Waste Reduction	
	End To End Supply Chain Management	
	Workforce Empowerment	
	Product And Process Design	
	Improved Resources And Inventory Utilisation	
	EMS	
	Reduced Energy Consumption And Emission	
Sustainability oriented innovation	Long Term Relationship With Customers	Klewitz et al., 2018, Adams et al., (2016)
	CRM Effectiveness	
	Demand Uncertainty	
	Waste Reduction	
	End To End Supply Chain Management	
	Workforce Empowerment	
	Product And Process Design	
	Improved Resources And Inventory Utilisation	
	Reduced Energy Consumption And Emission	
	EMS	
	Employee engagement to CSR	
	Eco design	
	Greening material and packaging	
	CSR practise	
	Reduction energy consumption and emissions	
	Social Management-practices	
	CSR practices	
	Health and safety practices	
	Social Management Performance	
	CSR performance	
	Health and safety performance	

Figure 3 summarizes the conceptual DEA model, where lean practices and sustainability oriented innovation are taken as input variables, and SMEs' economic, operational, environmental and social performance are the output variables. The DEA model is used to identify the efficient and inefficient SMEs, which will aid inefficient SMEs to explore different ways of implementing lean-based sustainability oriented innovation practices to improve their sustainability performance (by learning from efficient SMEs, i.e. peers)

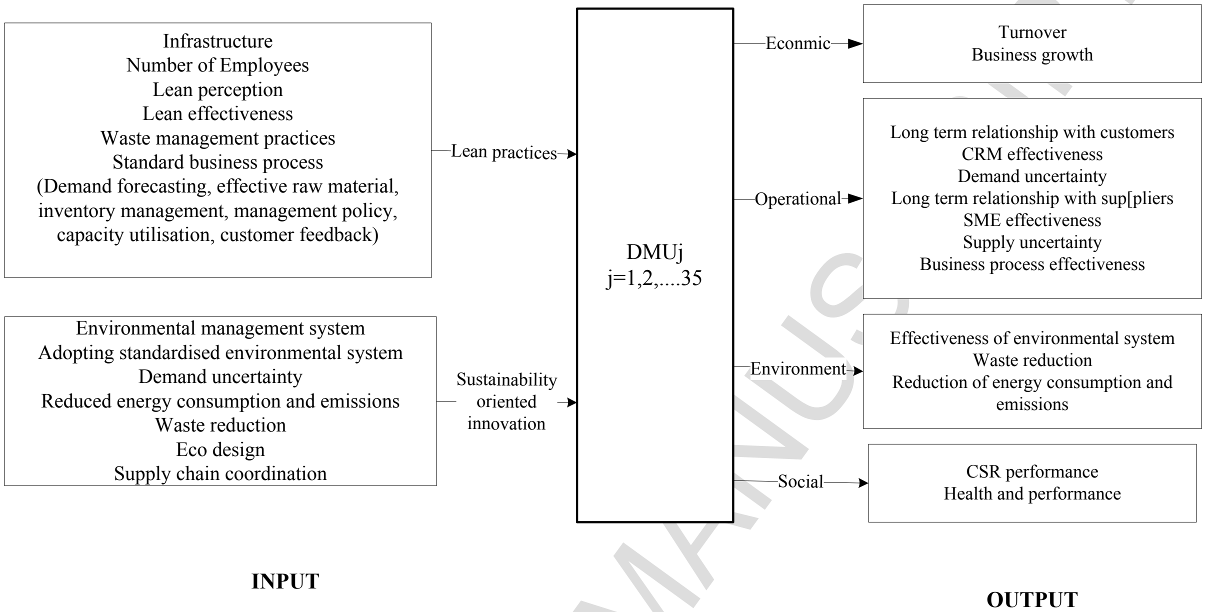

Figure 3 Conceptual model for DEA to measure the combined impact of lean and sustainability-oriented innovation on the sustainability performance of the SMEs

5 Application

Figure 4 summarizes the approach used for making recommendation to improve the performance through sustainability-oriented innovation and lean practices to SMEs. The input and output variables (obtained after the case studies) are fed to the DEA model. The result takes the form of a table (Table 4), which is used to first identify the efficient and inefficient DMUs. In this context, if the VRS value less than one, the corresponding DMU is inefficient, and the rank determines inefficiency relative to all other DMUs. Next, peers are assigned to the each inefficient DMU, i.e. benchmarking. The aim is to select a peer (SME), which has similar characteristics to the inefficient SME, to aid in making recommendations. This is achieved by selecting the peer with highest lambda value. Once the peer is selected, a comparative analysis is performed for two purposes: (1) Using the Returns to Scale (in Table 4) and Diff % columns (in Appendix 1), to understand whether the inefficient SME has to increase or decrease lean and sustainability oriented innovation for improving their sustainability performance; (2) Making recommendations to the inefficient SME for improving their performance, by looking at the lean and sustainability oriented innovation practices of the peer SME (i.e. learning from peer).

Table 4 shows efficiency summary of the participating Indian SMEs. From Table 4, shows that based upon VRS the 23 SMEs-DMUs are inefficient. There are SMEs with increasing return to scale (IRS), constant return to scale (CRS) and decreasing return to scale (DRS) respectively. The column 3 of table 4 shows the VRS efficiency of the 35 Indian SMEs. We assume the variable return to scale assumption to be suitable for the study. The analysis gives us the peers shown in the sixth column with which the SMEs should benchmark.

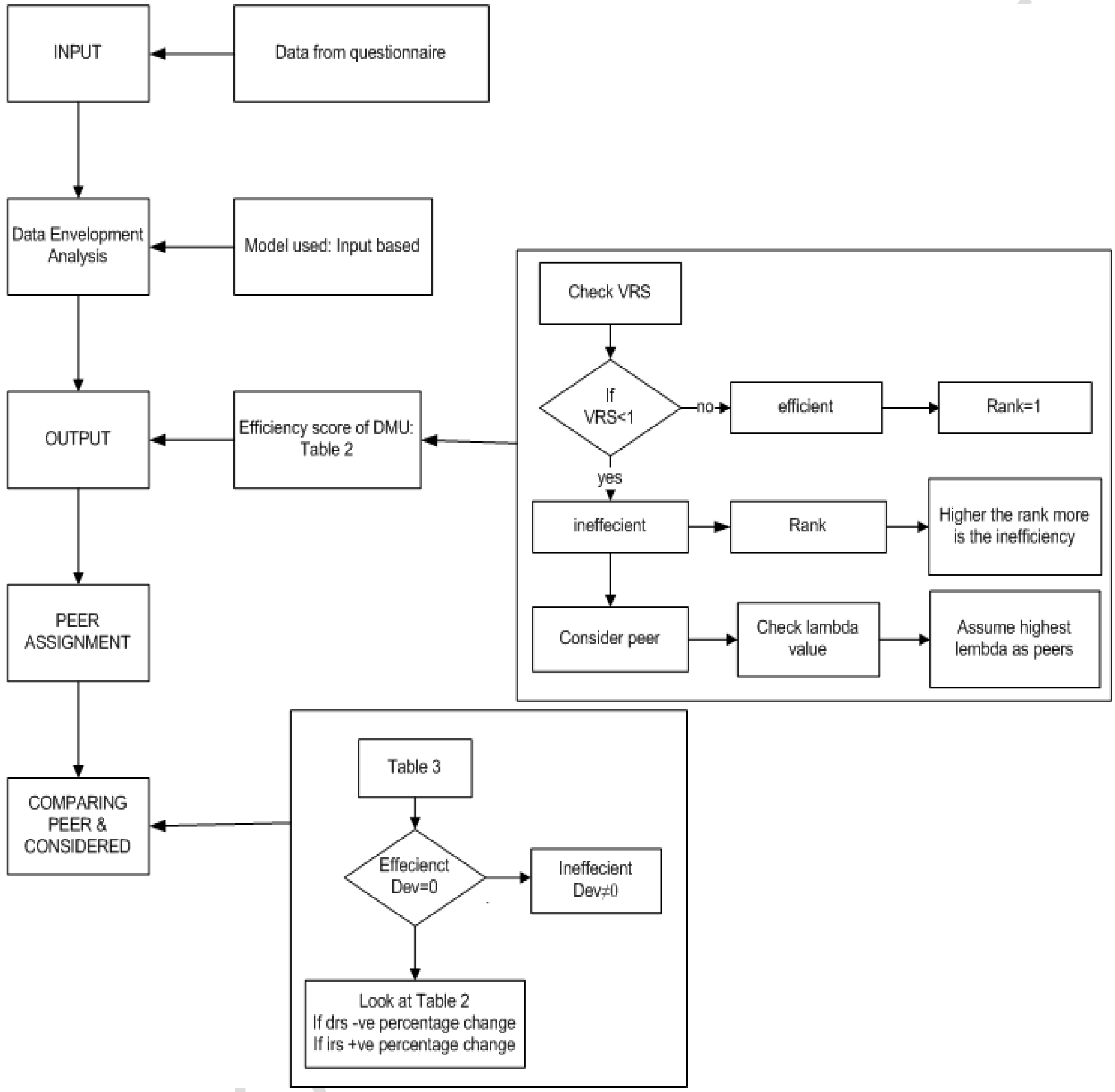

Figure 4 Analysing the results obtained from DEA for making recommendations to the SMEs

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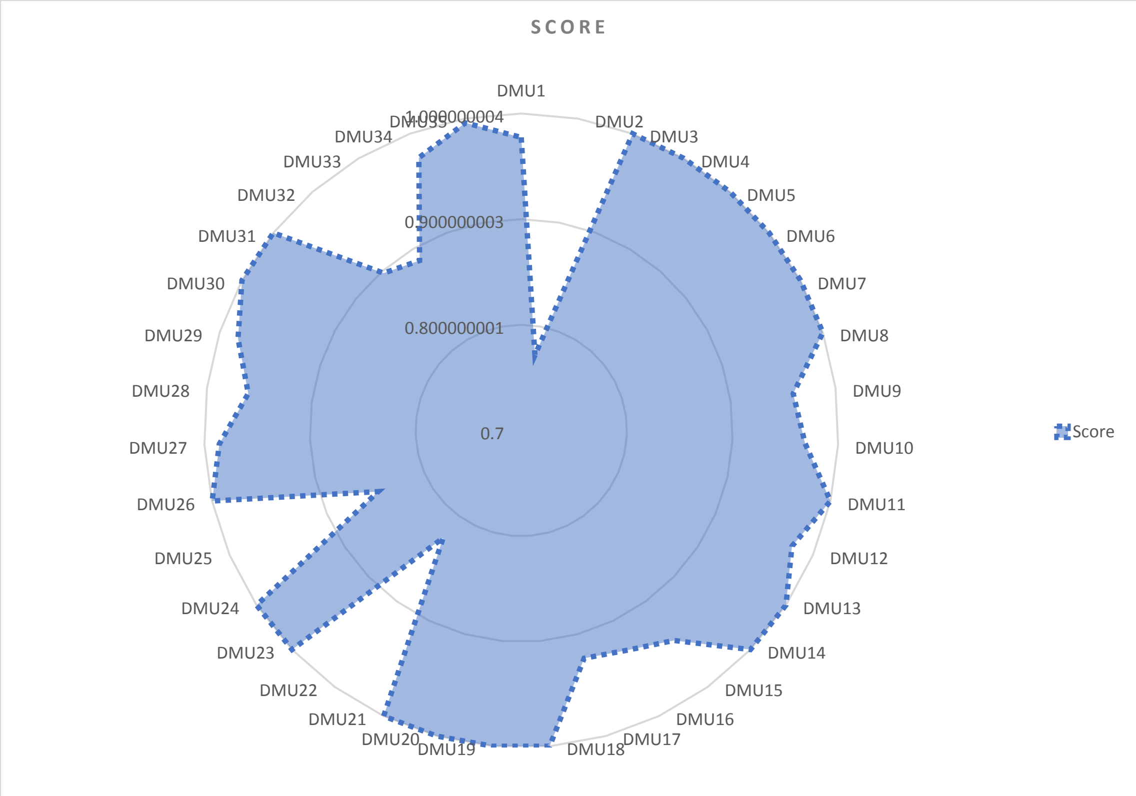

Figure 5 Radar representation of efficiency of the sample SMEs

Figure 5 depicts the results of the analysis of the efficiency of the sample SMEs. The SMEs on the score value 1 is identified as efficient. However, the SMEs not achieving the score of 1 are inefficient. The Table 4 represents the efficiency summary of the 35 Indian SMEs.

Table 4 Efficiency summary of 35 Indian SMEs

SMEs	CRS	VRS	SCALE efficiency	Returns to Scale	Peers	Rank
DMU1	0.969	0.977	0.992	drs	7 5 13 6 3	23
DMU2	0.763	0.772	0.989	drs	4 18 7 3 5 13	35
DMU3	1	1	1	-	3	1
DMU4	1	1	1	-	4	1
DMU5	1	1	1	-	5	1
DMU6	1	1	1	-	6	1
DMU7	0.951	1	0.951	drs	7	1
DMU8	0.958	1	0.958	drs	8	1
DMU9	0.956	0.96	0.996	irs	4 14 13 3 5	27
DMU10	0.968	0.97	0.998	drs	4 30 14 18 21 13	25
DMU11	1	1	1	-	11	1
DMU12	0.97	0.978	0.992	drs	4 13 3	22
DMU13	1	1	1	-	13	1
DMU14	1	1	1	-	14	1
DMU15	0.942	0.945	0.997	irs	13 3 14 6	28
DMU16	0.905	0.931	0.972	irs	24 3 11 21	29
DMU17	0.919	0.924	0.995	irs	21 6 5 14	30

DMU18	1	1	1	-	18	1
DMU19	0.929	1	0.929	drs	19	1
DMU20	0.949	1	0.949	drs	20	1
DMU21	1	1	1	-	21	1
DMU22	0.803	0.826	0.972	drs	21 7 6	34
DMU23	0.966	1	0.966	drs	23	1
DMU24	1	1	1	-	24	1
DMU25	0.837	0.847	0.988	drs	3 4 21 5 7 6	33
DMU26	0.832	1	0.832	drs	26	18
DMU27	0.92	0.986	0.933	drs	4 19 30 20	20
DMU28	0.939	0.96	0.978	drs	21 31 30 18	26
DMU29	0.976	0.981	0.994	irs	31 4 21 30 24	21
DMU30	1	1	1	-	30	1
DMU31	1	1	1	-	31	1
DMU32	0.889	0.898	0.99	drs	4 21 23 24	31
DMU33	0.849	0.887	0.957	drs	21 3 23 31 18	32
DMU34	0.912	0.976	0.935	drs	4 31 23 30 19	24
DMU35	0.948	0.997	0.952	drs	18 19 20 7	19

Note: (1) IRS, CRS and DRS denote the increasing returns to scale, constant return to scale, and decreasing returns to scale, respectively; (2) CRS, VRS denotes the efficiencies in CCR and BCC model in DEA respectively.

The case study has been conducted for case organisation DMU 1 (inefficient) and DMU 13 (efficient) to identify the potential recommendation for DMU1. The comparative analysis is discussed below. Looking into results presented in Tables 2, the inefficient case SME, DMU 2, can be benchmarked with the efficient DMU 4.

(Case description of DMU 1, DMU 2, DMU 13 and DMU 4 are attached in Appendix A2).

Case 1: DMU 1 benchmarks with DMU 13. SME 1 would benchmark to SME 13 and try to develop the SWOT strategies for its improvement. The table 5 shows the SWOT analysis of SME1 learning from SME 13. The improvements are based on the learning and benchmarking. Objective of the SWOT: To analyze the strength, weakness, opportunity and threats of the SME 1 and hence learn from benchmark company SME 13 to come up with the strength-opportunity strategy, strength-threat strategy, weakness-opportunity strategy, and weakness threats strategy.

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Table 5 SWOT analysis for the SME 1 learning from benchmark SME 13

Internal **External**	**Strength**	**Weakness**
	Long term relationship with customers Bid winning ability	Throughput not achieved Communication gaps between management Rejection rate is high Infrastructure issue Higher investment
Opportunity	**STRATEGIES**	
Demand Newer technology Flexibility	Customer relationship management Developing strategic relationship with a few customers	Improve quality Improve delivery time Reduce constant Make flat hierarchy
Threat Labor Market Competition Uncertainty in supply	Supplier Relationship Management Risk Management Collaboration with competitors for bigger procurement	Train manpower to cope with the uncertainty

Strengths: The company strengths are it has long term relationship with its customer. It ensures a stable market and ensures a reduced demand uncertainty. SME 1 also has a good bid winning capacity due to its innovative product design.

Weakness: The company struggles to achieve the throughput. The company struggles with lead time and on-time delivery. Additionally, there is a communication gaps between management. This leads to higher rejection of products. SME needs to re-organise themselves on the plant layout to reduce the movement of their man and material. The improvements require high investment.

Opportunity: The SME1 has a good demand and a stable market base. The SME has an opportunity to attract more customers due to newer technology. The flexibility of SME to produce different types of product help the SME play a significant part in the competition.

Threat: SME faces threat from the labor market. There are few unresolved employee and management issues which cannot be efficiently negotiated due to threats from union. The market is very competitive. The suppliers sometimes cause uncertainty in supply material.

Strength – opportunity strategy: A long term customer relationship management is required. It will help in developing strategic relationship with a few customers.

Strengths-threat: There is a need for the supplier Relationship Management. It will help to develop a better communication with the supplier and reduce the supplier uncertainty. The risk management needs to be practiced in the company. The SME can Collaborate with competitors for bigger procurement and tendering.

Weakness- opportunity: Improve quality of the products which will reduce the rejection rate. The delivery time-throughput is the critical issue so proper optimisation of the process needs to be done. To remove the communication gap between the management, flat hierarchy of the company should be practiced.

Weakness and threat: Train manpower to cope with the uncertainty.

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Projects developed from the above SWOT analysis indicate improvement strategies required for process improvement. Process improvement which leads to developing customer relationship management, supplier relationship management and reduction in the inventory. There is a requirement of improvement in quality and establishing long-term relationship. The improvement program needs to include a skill development of manpower by appropriate training. Implementing the ERP is needed for the integration of the process at different levels of the supply chain.

Case 2: DMU 2 benchmarks with DMU 4. SME 2 would benchmark to SME 4 and try to develop the SWOT strategies for its improvement. Table 6 shows the SWOT analysis for the SME2 learning from benchmark SME 4.The improvements are based on the learning and benchmarking with SME 4.
Objective of the SWOT: To analyse the strength, weakness, opportunity and threats of the SME 2 and hence learn from benchmark company SME 4. It helps SME 2 to come up with the strength-opportunity strategy, strength-threat strategy, weakness-opportunity strategy, and weakness threats strategy.
Strengths: The company is very competitive as it is able to offer significant low-price products at reasonable good quality and in time.
Weakness: The company struggles with ineffective inventory management, ineffective capacity utilisation, and is less efficient with the manpower it employs. The company has lack of cross functional cooperation. Employee well-being is a major concern. Their major focus remains on the economic practices. The employees face grave safety issues. The company has logistics issue and practice high manual intervention due to using cheap manpower.
Opportunity: The SME 2 has a good demand and a stable market base. The low-cost produce faces stiff competition in the market.
Threat: High maintenance cost of the production, competition, uncertainty in the market, union and government regulation pose threat to the organisation.
Strength – opportunity strategy: There is a need for machine replacement: manual to semi-automatic, training manpower, optimisation of the work process and limited overtime to be given to the employees.
Strengths-threat: There is a need for training manpower, optimisation of the work process and limited overtime to be given to the employees.
Weakness- opportunity: Weakness and threats: There is a potential for eco design, work in progress inventory and waste management practices.

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Table 6 SWOT analysis for solving the SME 2 learning from benchmark SME 4

Internal	**Strength**	**Weakness**
External	Cost cutting Reasonable good quality On time delivery	Ineffective inventory management Ineffective capacity utilisation Less efficient Lack of cross functional cooperation Employee well being major focus on economic practices Safety issues Major focus on the economic practices Safety issues Logistics issue High manual intervention Cheap manpower
Opportunity	**STRATEGY**	
Demand High competitiveness	Machine replacement: manual to semi-automatic	Eco design Work In Progress inventory Waste management Practices
Threat	Training manpower optimization Limited overtime	
High maintenance cost of the production Competition Uncertainty in the market Union Government Regulation		

Projects developed from the above SWOT analysis indicate improvement strategies are required. There is a need for machine replacement: manual to semi-automatic, training manpower, optimisation of the work process and limited overtime to be given to the employees. There is a potential for eco design, work in progress inventory and waste management practices. The above peer benchmark has been possible done by benchmarking it with the proper SMEs.

Discussion:

Lean practices are essentially efficiency focused approaches, which emphasize on waste reduction, and productivity improvement. Therefore, lean by default helps to achieve sustainability of SMEs through reducing cost, enhancing quality and addressing various environmental issues such as energy and waste reduction and resource efficiency (Inman and Green,2018). However, many lean approaches may not be environmental and social friendly (e.g. usage of raw materials that are low cost but not environment friendly, training cost, reduction etc.) (Piercy et al., 2015). Lean principle provides technical solution but fails to integrate social and environmental aspects to achieve sustainability. Approaching sustainability needs both social aspects as well as technical aspects. Sustainability oriented innovation can provide the social, environment aspect required to approach sustainability. Unlike lean, innovation emphasizes on responsiveness (customers' satisfaction) over efficiency to facilitate achieving sustainability. This study was able to highlight the impact of lean principle and SOI on sustainability of SMEs' supply chain. Lean practices focus only on the process improvement while SOI focuses on product, process and organization innovation. Lean principles are very focused (Piercy et al., 2015) while SOI are broad focus hence a tradeoff helps in achieving the sustainability. The study identified there are commonalities when trying to implement lean and sustainability-oriented innovation principles to achieve sustainability.

SWOT analysis and the case considered show that because of both lean and SOI can help achieve sustainability. Studies have said lean and SOI help achieve sustainability (Piercy et al.,2015; Klewitz et al.,2016). The four case studies clearly indicate the lean practices and SOI helps in approaching Sustainability of the SMEs supply chain. The comparison of the case study shows that the SME1 and SME 2 have lean practices but to implement lean SOI is required. (This is in consideration with the prior studies of Florida (1996),Piery et al., (2015)).

Lean practices can prohibit approaching sustainability due to the cost associated in implementing lean while the innovation can help SMEs approach sustainability (Benner and Tushman , 2003). The proposed framework helps SMEs to adopt suitable strategy and plans to improve their sustainability. Various lean and sustainability-oriented innovation practices are considered as input criteria, and economic, operational, environmental and social criteria are considered as output. As it is impossible to get secondary information of these criteria this study gathered primary data from a group of SMEs in a specific region (Eastern part of India) using a questionnaire through interviews with the key personnel. This research adopts Data Envelopment Analysis (DEA) as a technique to analyse efficiency of the participating SMEs with respect lean and sustainability-oriented innovation practices and sustainability performance. DEA is the most appropriate method for analysing efficiency of the SMEs over other contemporary methods such as multiple criteria decision-making methods (e.g. the AHP, ANP, Fuzzy etc.) due to nature of the problem and characteristics of the criteria for the proposed framework of analysis.

The results reveal that SMEs can approach sustainability through adopting specific process of lean and sustainability-oriented innovation. The proposed DEA – based framework for analysing impact of lean and sustainability-oriented innovation on sustainability performance helps SMEs achieve sustainability through adopting right combination of lean and sustainability-oriented innovation practices. This framework is useful to policymakers to segregate efficient SMEs and suggest improvement measures for the inefficient SMEs by proving funds and facilitating their business growth by objectively determining how to enhance their sustainability. This framework is useful to the individual SME in order derive their specific state of sustainability and improvement measures if inefficient through benchmarking with their peers.

Our methods has implications both for researcher and policy makers. Previous studies have not included all aspects of sustainability and fail to provide individual solutions to each SME. This framework has been able to help policy makers make appropriate comparison with the peers.

Based on the results and methods demonstrated above, this study helps managers and policy makers in three ways: firstly, to focus on segregation of SMEs into efficient and inefficient SMEs. Secondly it helps the SMEs to benchmark themselves with appropriate peers SMEs and thirdly develop their own SWOT derived strategies and projects after learning from the benchmark SMEs. The interaction with benchmark SMEs help them identify the common interactions and inspires themselves with the idea to identify their own improvement projects.

Conclusion:

This study reports on a case study approach as how SMEs can be segregated considering the lean and SOI as input for the Supply chain sustainability. From the study and recommendations, it was shown how lean and SOI strategies can help in achieving sustainability. The previous study failed to segregate and propose solution to SOI and Lean practices considered for improving sustainability.

From managerial perspective this study has clear implications. The framework can be used as a tool to benchmark the performance of SMEs and aid as a tool in improving SMEs supply chain sustainability. The suggestions made available and peer benchmarking can help SMEs to improve their supply chain sustainability. In the paper a wide explanation as how to use the framework as tool is explained. This will provide policy makers and stakeholders a clear tool to assess and make required improvements.

Contribution:

This research contributes to the existing Supply chain sustainability measurement literature.

Data Envelopment Model: this particular DEA model can help the SMEs assess their efficiency and segregate themselves based on their lean and SOI practices. The study has been able to give a framework to analyses the efficiency of the SMEs considering the lean and SOI as practices. This is of interest to policy maker, consortium/ cluster of SMEs as they will be able to use the framework to segregate the SMEs into efficient and inefficient SMEs. The framework would help in giving a summarized overview of the SME characteristics within a region identified as an inefficient SMEs, pair them with inefficient SMEs and improve their sustainability by striving a suitable balance between lean and SOI.

SME managers: DEA helps in pairing and collaborate with appropriate peers. The framework helps to formally adopt, implement appropriate strategies and harness best practices, which have been deemed suitable and beneficial from the benchmarking and SWOT analysis.

Limitations:

The aim of the study is to propose a framework to segregate the efficiency of SMEs supply chain sustainability based on their lean and SOI practices. However, the study does face limitations in the nature, size of the industries and sample of the study which limits it from generalisation. The study was conducted in the Eastern part of India. The SMEs taken in consideration are Indian manufacturing SMEs and may not be generalised to other countries due to difference in lean and SOI implementation in different economies (M. Dora et al., 2016).

Future directions:

However, this study has highlighted the insights for future trends in the research. It has been evident from the literature and conducted case study that SMEs and policy makers can look forward for understanding and monitoring their efficiency. Future research is possible to look forward to study between different regions, and economies. It will be an interesting study to see the impact of the policy, funding and legislation on lean and SOI on its impact on Supply

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chain sustainability. Further study can be done to study the impact of the CSR along with lean and SOI on the Supply chain sustainability of SMEs.

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				Lean Practice			Innovation			Economic performance			Operation Performance			Environment performance			Social performance		
No.	DMU	Score	Rank	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
1	DMU1	0.98	23	3.69	3.61	2.27	3.33	3.25	2.27	4.50	4.50	0.00	3.20	4.09	27.90	0.98	23.00	3.69	3.61	2.27	3.33
2	DMU2	0.77	35	4.03	3.11	22.75	4.38	3.38	22.75	4.50	4.50	0.00	3.90	3.90	0.00	0.77	35.00	4.03	3.11	22.75	4.38
3	DMU3	1.00	1	2.69	2.69	0.00	3.13	3.13	0.00	3.50	3.50	0.00	3.23	3.23	0.00	1.00	1.00	2.69	2.69	0.00	3.13
4	DMU4	1.00	1	3.03	3.03	0.00	3.43	3.43	0.00	5.50	5.50	0.00	3.93	3.93	0.00	1.00	1.00	3.03	3.03	0.00	3.43
5	DMU5	1.00	1	3.76	3.76	0.00	3.08	3.08	0.00	6.00	6.00	0.00	4.27	4.27	0.00	1.00	1.00	3.76	3.76	0.00	3.08
6	DMU6	1.00	1	3.76	3.76	0.00	3.15	3.15	0.00	4.50	4.50	0.00	4.24	4.24	0.00	1.00	1.00	3.76	3.76	0.00	3.15
7	DMU7	1.00	1	4.40	4.40	0.00	4.03	4.03	0.00	5.50	5.50	0.00	4.68	4.68	0.00	1.00	1.00	4.40	4.40	0.00	4.03
8	DMU8	1.00	1	3.29	3.29	0.00	3.98	3.98	0.00	4.50	4.50	0.00	3.68	3.68	0.00	1.00	1.00	3.29	3.29	0.00	3.98
9	DMU9	0.96	27	3.10	2.97	4.04	3.10	2.97	4.04	4.50	4.50	0.00	3.58	3.58	0.00	0.96	27.00	3.10	2.97	4.04	3.10
10	DMU10	0.97	25	3.14	3.04	3.13	3.03	2.94	3.13	3.50	3.50	0.00	4.02	4.02	0.00	0.97	25.00	3.14	3.04	3.13	3.03
11	DMU11	1.00	1	2.14	2.14	0.00	3.09	3.09	0.00	2.00	2.00	0.00	2.92	2.92	0.00	1.00	1.00	2.14	2.14	0.00	3.09
12	DMU12	0.98	22	3.03	2.96	2.15	3.47	3.39	2.17	4.50	4.50	0.00	3.45	3.77	9.53	0.98	22.00	3.03	2.96	2.15	3.47
13	DMU13	1.00	1	3.11	3.11	0.00	3.59	3.59	0.00	3.50	3.50	0.00	4.02	4.02	0.00	1.00	1.00	3.11	3.11	0.00	3.59
14	DMU14	1.00	1	2.86	2.86	0.00	2.23	2.23	0.00	4.50	4.50	0.00	3.80	3.80	0.00	1.00	1.00	2.86	2.86	0.00	2.23
15	DMU15	0.95	28	3.71	3.51	5.44	3.40	3.21	5.44	3.50	4.20	20.14	4.08	4.08	0.00	0.95	28.00	3.71	3.51	5.44	3.40
16	DMU16	0.93	29	3.17	2.95	6.92	2.48	2.31	6.92	4.00	4.05	1.28	3.64	3.78	4.03	0.93	29.00	3.17	2.95	6.92	2.48
17	DMU17	0.92	30	3.96	3.66	7.64	3.25	3.00	7.64	5.00	5.00	0.00	4.09	4.20	2.84	0.92	30.00	3.96	3.66	7.64	3.25
18	DMU18	1.00	1	3.03	3.03	0.00	3.40	3.40	0.00	2.00	2.00	0.00	4.10	4.10	0.00	1.00	1.00	3.03	3.03	0.00	3.40
19	DMU19	1.00	1	4.40	4.40	0.00	4.30	4.30	0.00	6.00	6.00	0.00	4.69	4.69	0.00	1.00	1.00	4.40	4.40	0.00	4.30
20	DMU20	1.00	1	3.76	3.76	0.00	3.53	3.53	0.00	5.00	5.00	0.00	4.61	4.61	0.00	1.00	1.00	3.76	3.76	0.00	3.53
21	DMU21	1.00	1	3.46	3.46	0.00	1.78	1.78	0.00	5.00	5.00	0.00	4.54	4.54	0.00	1.00	1.00	3.46	3.46	0.00	1.78
22	DMU22	0.83	34	4.84	3.93	18.90	3.80	3.14	17.43	5.00	5.00	0.00	4.39	4.48	2.00	0.83	34.00	4.84	3.93	18.90	3.80
23	DMU23	1.00	1	4.61	4.61	0.00	3.65	3.65	0.00	7.00	7.00	0.00	4.55	4.55	0.00	1.00	1.00	4.61	4.61	0.00	3.65
24	DMU24	1.00	1	2.24	2.24	0.00	1.65	1.65	0.00	4.00	4.00	0.00	2.54	2.54	0.00	1.00	1.00	2.24	2.24	0.00	1.65
25	DMU25	0.85	33	4.24	3.59	15.29	3.70	3.13	15.29	5.00	5.00	0.00	4.19	4.19	0.00	0.85	33.00	4.24	3.59	15.29	3.70
26	DMU26	1.00	18	4.57	4.57	0.01	4.18	4.18	0.01	5.50	5.50	0.00	4.71	4.71	0.00	1.00	18.00	4.57	4.57	0.01	4.18
27	DMU27	0.99	20	3.71	3.66	1.41	3.50	3.42	2.42	5.50	5.50	0.00	4.44	4.44	0.00	0.99	20.00	3.71	3.66	1.41	3.50

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28	DMU28	0.96	26	3.47	3.33	3.95	2.68	2.57	3.95	4.50	4.50	0.00	4.50	4.50	0.00	0.96	26.00	3.47	3.33	3.95	2.68
29	DMU29	0.98	21	3.04	2.98	1.83	2.68	2.63	1.83	5.00	5.00	0.00	4.06	4.06	0.00	0.98	21.00	3.04	2.98	1.83	2.68
30	DMU30	1.00	1	2.93	2.93	0.00	2.53	2.53	0.00	5.00	5.00	0.00	4.20	4.20	0.00	1.00	1.00	2.93	2.93	0.00	2.53
31	DMU31	1.00	1	3.36	3.36	0.00	2.83	2.83	0.00	4.83	4.83	0.00	4.60	4.60	0.00	1.00	1.00	3.36	3.36	0.00	2.83
32	DMU32	0.90	31	3.61	3.24	10.22	2.68	2.41	10.22	5.17	5.17	0.00	3.94	3.99	1.38	0.90	31.00	3.61	3.24	10.22	2.68
33	DMU33	0.89	32	4.21	3.74	11.26	3.60	3.19	11.26	5.00	5.00	0.00	3.93	4.41	12.32	0.89	32.00	4.21	3.74	11.26	3.60
34	DMU34	0.98	24	3.54	3.45	2.43	3.35	3.04	9.29	5.50	5.50	0.00	4.34	4.34	0.00	0.98	24.00	3.54	3.45	2.43	3.35
35	DMU35	1.00	19	3.64	3.62	0.42	3.63	3.61	0.42	4.00	4.05	1.23	4.44	4.44	0.00	1.00	19.00	3.64	3.62	0.42	3.63

Table A1 Efficiency summary of 35 Indian SMEs

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Table A2
Case description of DMU1, DMU2, DMU 13 and DMU 4.

<table>
<tr><th>Name</th><th>product</th><th>Industry Type</th><th>Turnover</th><th>Number Of Employees</th></tr>
<tr><td>DMU1</td><td>Jigs and fixtures</td><td rowspan="4">Manufacturing</td><td>1.5 crore</td><td>38</td></tr>
<tr><td>DMU2</td><td>springs</td><td>4 crore</td><td>60</td></tr>
<tr><td>DMU13</td><td>Manufacturing of Fuel Dispensing Pump, meter for volumetric measurement.</td><td>66666600Rs</td><td>48</td></tr>
<tr><td>DMU4</td><td>Parts for ordinance factory</td><td>2 crore</td><td>34</td></tr>
</table>

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Table 5 SWOT analysis for the SME 1 learning from benchmark SME 13

Internal **External**	**Strength**	**Weakness**
	Long term relationship with customers Bid winning ability	Throughput not achieved Communication gaps between management Rejection rate is high Infrastructure issue Higher investment
Opportunity	**STRATEGIES**	
Demand Newer technology Flexibility	Customer relationship management Developing strategic relationship with a few customers	Improve quality Improve delivery time Reduce constant Make flat hierarchy
Threat	Supplier Relationship Management Risk Management Collaboration with competitors for bigger procurement	Train manpower to cope with the uncertainty
Labor Market Competition Uncertainty in supply		

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Table 6 SWOT analysis for solving the SME 2 learning from benchmark SME 4

<table>
<tr><td rowspan="2">Internal

External</td><td>Strength</td><td>Weakness</td></tr>
<tr><td>Cost cutting
Reasonable good quality
On time delivery</td><td>Ineffective inventory management
Ineffective capacity utilisation
Less efficient
Lack of cross functional cooperation
Employee well being
major focus on economic practices
Safety issues
Major focus on the economic practices
Safety issues
Logistics issue
High manual intervention
Cheap manpower</td></tr>
<tr><td rowspan="2">Opportunity</td><td colspan="2">STRATEGY</td></tr>
<tr><td rowspan="2">Machine replacement: manual to semi-automatic</td><td rowspan="4">Eco design
Work In Progress inventory
Waste management Practices</td></tr>
<tr><td>Demand
High competitiveness</td></tr>
<tr><td>Threat</td><td rowspan="2">Training manpower optimization
Limited overtime</td></tr>
<tr><td>High maintenance cost of the production
Competition
Uncertainty in the market
Union
Government Regulation</td></tr>
</table>

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				Lean Practice			Innovation			Economic performance			Operation Performance			Environment performance			Social performance		
No.	DMU	Score	Rank	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)	Data	Projection	Diff.(%)
1	DMU1	0.98	23	3.69	3.61	2.27	3.33	3.25	2.27	4.50	4.50	0.00	3.20	4.09	27.90	0.98	23.00	3.69	3.61	2.27	3.33
2	DMU2	0.77	35	4.03	3.11	22.75	4.38	3.38	22.75	4.50	4.50	0.00	3.90	3.90	0.00	0.77	35.00	4.03	3.11	22.75	4.38
3	DMU3	1.00	1	2.69	2.69	0.00	3.13	3.13	0.00	3.50	3.50	0.00	3.23	3.23	0.00	1.00	1.00	2.69	2.69	0.00	3.13
4	DMU4	1.00	1	3.03	3.03	0.00	3.43	3.43	0.00	5.50	5.50	0.00	3.93	3.93	0.00	1.00	1.00	3.03	3.03	0.00	3.43
5	DMU5	1.00	1	3.76	3.76	0.00	3.08	3.08	0.00	6.00	6.00	0.00	4.27	4.27	0.00	1.00	1.00	3.76	3.76	0.00	3.08
6	DMU6	1.00	1	3.76	3.76	0.00	3.15	3.15	0.00	4.50	4.50	0.00	4.24	4.24	0.00	1.00	1.00	3.76	3.76	0.00	3.15
7	DMU7	1.00	1	4.40	4.40	0.00	4.03	4.03	0.00	5.50	5.50	0.00	4.68	4.68	0.00	1.00	1.00	4.40	4.40	0.00	4.03
8	DMU8	1.00	1	3.29	3.29	0.00	3.98	3.98	0.00	4.50	4.50	0.00	3.68	3.68	0.00	1.00	1.00	3.29	3.29	0.00	3.98
9	DMU9	0.96	27	3.10	2.97	4.04	3.10	2.97	4.04	4.50	4.50	0.00	3.58	3.58	0.00	0.96	27.00	3.10	2.97	4.04	3.10
10	DMU10	0.97	25	3.14	3.04	3.13	3.03	2.94	3.13	3.50	3.50	0.00	4.02	4.02	0.00	0.97	25.00	3.14	3.04	3.13	3.03
11	DMU11	1.00	1	2.14	2.14	0.00	3.09	3.09	0.00	2.00	2.00	0.00	2.92	2.92	0.00	1.00	1.00	2.14	2.14	0.00	3.09
12	DMU12	0.98	22	3.03	2.96	2.15	3.47	3.39	2.17	4.50	4.50	0.00	3.45	3.77	9.53	0.98	22.00	3.03	2.96	2.15	3.47
13	DMU13	1.00	1	3.11	3.11	0.00	3.59	3.59	0.00	3.50	3.50	0.00	4.02	4.02	0.00	1.00	1.00	3.11	3.11	0.00	3.59
14	DMU14	1.00	1	2.86	2.86	0.00	2.23	2.23	0.00	4.50	4.50	0.00	3.80	3.80	0.00	1.00	1.00	2.86	2.86	0.00	2.23
15	DMU15	0.95	28	3.71	3.51	5.44	3.40	3.21	5.44	3.50	4.20	20.14	4.08	4.08	0.00	0.95	28.00	3.71	3.51	5.44	3.40
16	DMU16	0.93	29	3.17	2.95	6.92	2.48	2.31	6.92	4.00	4.05	1.28	3.64	3.78	4.03	0.93	29.00	3.17	2.95	6.92	2.48
17	DMU17	0.92	30	3.96	3.66	7.64	3.25	3.00	7.64	5.00	5.00	0.00	4.09	4.20	2.84	0.92	30.00	3.96	3.66	7.64	3.25
18	DMU18	1.00	1	3.03	3.03	0.00	3.40	3.40	0.00	2.00	2.00	0.00	4.10	4.10	0.00	1.00	1.00	3.03	3.03	0.00	3.40
19	DMU19	1.00	1	4.40	4.40	0.00	4.30	4.30	0.00	6.00	6.00	0.00	4.69	4.69	0.00	1.00	1.00	4.40	4.40	0.00	4.30
20	DMU20	1.00	1	3.76	3.76	0.00	3.53	3.53	0.00	5.00	5.00	0.00	4.61	4.61	0.00	1.00	1.00	3.76	3.76	0.00	3.53
21	DMU21	1.00	1	3.46	3.46	0.00	1.78	1.78	0.00	5.00	5.00	0.00	4.54	4.54	0.00	1.00	1.00	3.46	3.46	0.00	1.78
22	DMU22	0.83	34	4.84	3.93	18.90	3.80	3.14	17.43	5.00	5.00	0.00	4.39	4.48	2.00	0.83	34.00	4.84	3.93	18.90	3.80
23	DMU23	1.00	1	4.61	4.61	0.00	3.65	3.65	0.00	7.00	7.00	0.00	4.55	4.55	0.00	1.00	1.00	4.61	4.61	0.00	3.65
24	DMU24	1.00	1	2.24	2.24	0.00	1.65	1.65	0.00	4.00	4.00	0.00	2.54	2.54	0.00	1.00	1.00	2.24	2.24	0.00	1.65
25	DMU25	0.85	33	4.24	3.59	15.29	3.70	3.13	15.29	5.00	5.00	0.00	4.19	4.19	0.00	0.85	33.00	4.24	3.59	15.29	3.70

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26	DMU26	1.00	18	4.57	4.57	0.01	4.18	4.18	0.01	5.50	5.50	0.00	4.71	4.71	0.00	1.00	18.00	4.57	4.57	0.01	4.18
27	DMU27	0.99	20	3.71	3.66	1.41	3.50	3.42	2.42	5.50	5.50	0.00	4.44	4.44	0.00	0.99	20.00	3.71	3.66	1.41	3.50
28	DMU28	0.96	26	3.47	3.33	3.95	2.68	2.57	3.95	4.50	4.50	0.00	4.50	4.50	0.00	0.96	26.00	3.47	3.33	3.95	2.68
29	DMU29	0.98	21	3.04	2.98	1.83	2.68	2.63	1.83	5.00	5.00	0.00	4.06	4.06	0.00	0.98	21.00	3.04	2.98	1.83	2.68
30	DMU30	1.00	1	2.93	2.93	0.00	2.53	2.53	0.00	5.00	5.00	0.00	4.20	4.20	0.00	1.00	1.00	2.93	2.93	0.00	2.53
31	DMU31	1.00	1	3.36	3.36	0.00	2.83	2.83	0.00	4.83	4.83	0.00	4.60	4.60	0.00	1.00	1.00	3.36	3.36	0.00	2.83
32	DMU32	0.90	31	3.61	3.24	10.22	2.68	2.41	10.22	5.17	5.17	0.00	3.94	3.99	1.38	0.90	31.00	3.61	3.24	10.22	2.68
33	DMU33	0.89	32	4.21	3.74	11.26	3.60	3.19	11.26	5.00	5.00	0.00	3.93	4.41	12.32	0.89	32.00	4.21	3.74	11.26	3.60
34	DMU34	0.98	24	3.54	3.45	2.43	3.35	3.04	9.29	5.50	5.50	0.00	4.34	4.34	0.00	0.98	24.00	3.54	3.45	2.43	3.35
35	DMU35	1.00	19	3.64	3.62	0.42	3.63	3.61	0.42	4.00	4.05	1.23	4.44	4.44	0.00	1.00	19.00	3.64	3.62	0.42	3.63

Table A1 Efficiency summary of 35 Indian SMEs

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